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by

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ABSTRACT

The existence of a plankton sampler which is capable of filtering a reasonably large volume of water but which need not be towed in order to perform this function would provide a means whereby the planktonologist could conduct his collection in areas which preclude towing operations or under circumstances where towing is inconvenient. A modification to the standard Clarke-Bumpus quantitative plankton sampler which provides such a capability is described and a calibration procedure is discussed. Results of comparative testing indicate the satisfactory operation of the modified sampler.

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1. Introduction.

The methods currently utilized in the investigation of plankton involve the use of collection devices falling into one of two categories; those which are towed and those which operate while at rest. The former category contains a variety of nets and mechanisms, many of which can be operated both in the horizontal and vertical. The latter category comprises those devices which instantaneously entrap a quantity of water and the attendant plankton population as well as pumping rigs which either convey their catch to the surface or filter it through a net at depths. Horizontal towing has proved to be a satisfactory method of sampling under normal circumstances; however, there are several situations in which this method is found to be difficult or impossible. For example, shoal water may represent a hazard to the towing vessel; research may be desired near an irregular bottom which could jeopardize the sampling device or ice cover may restrict the vessel's movements. In these instances the planktonologist is faced with the alternative of using a static sampler and must accept certain restrictions inherent in their design. Trapping devices are limited in the volume of water they can accommodate by virtue of their dimensions while pumping apparatus often require an inordinate amount of ancillary equipment and maintenance.

Figure 1 depicts the plankton sampler described by Clarke and Bumpus [1 & 2], with improvements by Paquette and Frolander [3], which offers an excellent opportunity for modification designed to permit its operation without the necessity of being towed. The impeller of the sampler, which is used to meter the flow of water, possesses excellent suction characteristics and, when actuated by an external force, is capable of creating a strong flow through the body. It is this characteristic which has led to the development of the modification described herein. In selecting a form of motive power, two sources were considered; electrical and mechanical. The use of an electric motor was felt to involve problems of design and ultimate configuration which would be inconsistent with the desire to develop a device which would be of relatively simple construction while entailing a general ease of operation. A spring-powered motor was concluded to be a suitable power source.

The modification described is not intended as an improvement, per se, to the normal operation of the Clarke-Bumpus sampler. Rather, it is intended to provide an easily affixed attachment which will result in a more flexible machine that can be operated in a wide range of environments. Considering the large number of Clarke-Bumpus samplers currently in the field, changes to the basic design have been purposely minimized and any small shop facility should find no difficulty in performing the alterations necessary to make the sampler compatible with the modification package.

2. Design and Construction.

The first consideration in designing this modification was the requirement of a stable platform that would provide support for the drive motor, permit a simple linkage between the motor and impeller shaft, contribute to the installation of a simple actuating and stopping linkage and entail a minimum amount of alteration to the basic sampling device.

With these points in mind, it was decided to extend the main body by manufacturing a sleeve which would attach to the body in the identical manner as the net adapter ring. Figure 2 shows the radial dimensions of this body extension. This component has been machined from stock aluminum pipe and was offset one-eighth inch after cutting the inside wall in order to produce a suitable platform on which to mount the motor unit. The fit of the forward end of the extension to the after end of the body is critical in that a loose mating here would ultimately lead to inconsistent mating of the gears connecting the motor drive shaft and the impeller shaft. Accordingly, this fit has been made as tight as is consistent with ease of connection and removal. The position of the locating slots on the forward end of the extension are also critical since they ensure that the platform area is parallel to the plane of the impeller shaft when the extension is affixed to the body. Figure 3 depicts the body extension as viewed from above. A one and one-quarter inch diameter hole is provided in the platform as access for the motor drive shaft and attached miter gear. The after end of the body extension has been machined to receive the forward reinforced canvas section of the plankton net thus obviating the requirement for an adapter ring as used with the basic sampler.

The body of the drive motor is comprised of three aluminum plates (Figures 4, 5, and 6) separated by 3/8 inch outer diameter spacer posts through which pass four 3/16 inch studs fitted to tapped holes in the bottom plate. Four 3/16 inch studs are fitted to tapped holes in the body extension and pass through corresponding holes in the upper plates to furnish a means of securing the drive motor to the body extension. Wing nuts are used here to facilitate separation of the motor unit and body extension (Figure 19). Locating pins are secured to the underside of the bottom plate to ensure accurate alignment of the motor unit on the platform. The bottom plate has been constructed of 17/32 inch plate milled to 5/64 inch, as shown in Figure 6, thus creating a system of ribs needed for rigidity while allowing space for the gear shaft ends and collars.

Figure 7, and its attendant data sheet, describe the gear train which is housed between the middle and bottom plates. This component is comprised of standard (non-precision) spur gears which serve to increase the revolutions between the motor spring and the output shaft while maintaining sufficient power to deliver the desired torque to the impeller. The ratio between the first pinion and the output shaft is 94.7:1 and from first pinion to the impeller is 73.7:1. Each gear shaft is supported by ball bearings secured in adjustable mountings attached to the middle and lower plates.

It was originally estimated that a motor type power spring capable of producing approximately two foot-pounds of energy would be necessary to drive the impeller, via the gear train, at close to 200 RPM for a minimum of five minutes. This estimate proved to be quite accurate. The dimensional characteristics of the spring are based, initially, on the torque requirement. A spring width of one inch is used to reduce thickness and, ultimately, space requirements. It has been determined that a spring of .025 inch thickness will produce a torque of 26.72 inch-pounds at maximum allowable stress,[1] a value which satisfies the estimated power requirements. The power spring is housed in an aluminum drum and wound on a steel arbor (Figure 8). Arbor diameter (A) should be from fifteen to twenty-five times spring thickness (h) and was therefore constructed with a diameter of one-half inch.[2] Fourteen turns of the arbor are required to produce the necessary impeller revolutions and since:

$$n = \frac{\sqrt{2(A^2+D^2)} - (A+D)}{2.55h},$$

where n is the number of arbor turns and D is the inside diameter of the drum,[3] a drum diameter of at least 3.5 inches was indicated. Further, since the maximum number of turns are obtained when:

$$D \geq \sqrt{2.55Lh + A^2},$$

where L is spring length,[4] a length of 137.5 inches was utilized. The outer end of the power spring is bolted to the drum wall and the opposite end is shaped to the curve of the arbor such that the securing hole in this end fits around a raised catching nib on the arbor. Figure 8 shows the drum-arbor design in which the arbor is pinned to the ratchet gear at its

[1]Handbook of Mechanical Spring Design ([n.p.] Assodicated Spring Corporation, 1955) p. 58.

[2]Ibid., p. 57.

[3]Ibid.

[4]Ibid.

upper extremity while the lower end rests on a 1/4 inch bearing ball. The lower end of the drum is pinned to the gear train first pinion shaft. The recessed center section of the drum supports the bearing ball on which the arbor rests. This construction permits the spring to be wound independent of the gear train. The upper part of the ratchet gear is machined to the dimensions of a 5/8 inch hexagonal nut (Figure 9). A modified 5/8 inch wrench socket serves as an adequate winding key.

Figures 10 and 19 show the motor cocking plunger, which is a spring loaded pin mounted on the middle plate. When the plunger is depressed it engages one of four slots in the face of gear D thus locking the gear train section of the drive motor. The cocking plunger is depressed by use of the cocking assist plunger mounted on the upper plate (Figure 11). The cocking plunger is held in the depressed position by the trigger mechanism which is shown in Figure 12. The shaft of the trigger mechanism slides over the top of the depressed cocking plunger against spring tension. When the sampler is in the normal fully cocked posture (gate held closed by the gate release catch), the trigger shaft is held in this position by the motor control plate attached to the gate release rod (Figures 2 and 20). As the sampler is actuated by a messenger, in the usual manner, the release rod rotates 90 degrees opening the body gate and simultaneously releases the trigger shaft which moves forward clearing the cocking plunger. The cocking plunger is now free to lift, unlocking the gear train which then responds to the applied spring tension.

When a second messenger acts to close the sampler gate, the gate release rod rotates another 90 degrees and, in so doing, the motor control plate strikes the stop rod which slides back to release the spring loaded stop plunger. This plunger engages one of four spokes on the stop sprocket attached to the upper end of the D and E gear shaft (Figure 13). This last operation applies a positive stop to the motor. Figure 14 is a side view of the assembled drive motor with the stop mechanism omitted for simplicity. Figure 15 shows the modified impeller shaft which has been extended to permit attachment of a miter gear for the purpose of mating with a similar gear on the drive motor output shaft. The impeller hub and worm gear are positioned on the shaft as before. The after impeller shaft support has been bored to permit free clearance of the shaft (Figure 21). Figures 16 and 21 show the horseshoe-shaped shaft support which has been designed to render the extended shaft compatible with the sampler when the instrument is operated under tow. This support incorporates the adjustable bearing feature of the original.

The rudder mount (Figures 17 and 22) is secured to the motor body to permit attachment of a rudder which functions to keep the sampler facing into the flow of any existing current. The rudder is constructed of 1/16 inch aluminum plate and has an area of approximately 50 square inches. The actual design of the rudder is arbitrary; however, care has been taken to ensure ample free space between the lower extremity of the rudder and the plankton net.

When towed, the sampler is maintained in a horizontal attitude by water pressure acting on the two body vanes. The modified procedure requires that the sampler be held in the horizontal by other means. This is accomplished by inserting the locking rod (Figure 18) through the two net support rod securing posts and attaching the rod to the frame cross-support plate. Additional securing posts are provided on the side of the bottom plate (Figure 6). A three inch glass fishing net float, wrapped in foam rubber, is attached to the after end of the rudder to assist in keeping the sampler properly oriented.

Figures 19, 22 and 23 depict the drive motor mounted on the body extension. Figure 24 shows the completely assembled modified sampler.

3. Calibration.

The basic Clarke-Bumpus sampler, being a quantitative instrument, incorporates a means of determining the total volume of water filtered during a run. This is provided for by the revolutions counter which operates in response to the rotation of the impeller. The amount of water, in liters, which has passed through the body of the sampler can be determined by multiplying the counter reading by a calibration factor. The calibration factor of 4, as suggested by Clarke and Bumpus,[5] has been confirmed by Yentsch and Duxbury for a maximum (and acceptable) resultant error of

[5] Clarke, G. L. and Bumpus, D. F., The Plankton Sampler-an Instrument for Quantitative Plankton Investigations (Baltimore: American Society of Limnology and Oceanography, Spec. Publ. No. 5, Rev., 1950) pp. 1-8.

15 percent.[6] Since this factor pertains for a situation wherein water flowing through the sampler acts on the impeller, it was necessary to perform a re-calibration for the situation in which the impeller is the prime mover.

Several calibration procedures were investigated and, considering the availability of equipment and facilities, it was decided to make a direct measurement of the flow velocity through the sampler body. Figure 25 shows the modified Clarke-Bumpus sampler with an Ekman Current meter attached to measure the flow rate. Since flow through the sampler diminishes with time as spring tension decreases, current readings were taken at 30 second intervals. Tests were performed in a large swimming pool in approximately three feet of still water. A total of ten runs were conducted and current values averaged for each time increment. With known cross-sectional area of the sampler orifice, the volume rate of flow is easily computed and, subsequently, the volume of flow, in liters, for each time increment is established.

The average running time was 9.5 minutes which represents the maximum operating period of the modified sampler. Flow velocity was observed to vary from a maximum value of 1.23 feet per second early in the run to a minimum of 0.18 feet per second at the end. Based on the above calculations, it was determined that approximately 1000 liters of water are filtered during the first 5 minutes of operation and approximately

[6] Yentsch, C.S. and Duxbury, A.C., Some of the Factors Affecting the Calibration of the Clarke-Bumpus Quantitative Plankton Sampler (Baltimore: American Society of Limnology and Oceanography, v. 1 (4), October, 1956) p. 271.

500 liters during the remaining 4.5 minutes. During the calibration runs, counter readings were noted at the same time as current values. These readings were then related to corresponding volumes of flow, resulting in a counter calibration factor of 2.0 liters per count. Calibration was conducted using both number 2 and number 20 mesh nets with no appreciable differences noted in the calibration factor determined with each.

Additional runs were conducted with currents simulated by towing the modified sampler at increments of one knot up to a maximum of five knots. It was theorized that the presence of a current acting to force water through the sampler body would alleviate the resistance to the impeller rotation thus resulting in an increase in the counter reading proportional to the increased flow. Calibration data revealed, however, that this theory is not valid for currents in excess of one knot. Beyond this velocity, the true calibration factor increases as water is forced past the impeller without a corresponding increase in the impeller rotation. The still water calibration factor of 2.0 is valid, within a fifteen percent error allowance, for currents to one knot. The following is a tabulation of calibration factors which should be applied to counter readings when operating the modified sampler in currents over one knot:

Current Velocity (knots)	Calibration Factor
1.5	2.5
2.0	2.8
2.5	3.0
3.0	3.2
3.5	3.5
4.0	3.7
4.5	3.9
5.0	4.1

Although by virtue of the calibration procedures followed, the above factors are less susceptible to error caused by rejection of water encountered by the sampler, the effects of net clogging offer a source of large error. Should clogging occur, the standard procedure of performing a shortened run should be followed. [5]

4. Test and Evaluation.

A proper determination of the modified sampler's operability and effectiveness required a program of actual testing in which results were compared to an acceptable standard. Accordingly, a series of test runs with the modified sampler were conducted in Monterey Bay, California using the unmodified device as a standard. As a first step, plankton were obtained by towing the unmodified sampler for approximately five minutes. Immediately thereafter, the modification package was installed and samples obtained at the same depth. During this phase an Ekman current meter was lowered for the purpose of determining current velocity. In addition, static runs were conducted adjacent to the pier area. The following is a compilation of test results:

TEST RUN NUMBER ONE

	Unmodified Sampler	Modified Sampler
Current (Knots)	-	3.5
Calibration Factor	4.0	3.5
Total Flow (Liters)	3440	2040
Plankton Catch (ML)	15	10
Plankton Density (ML/L)	0.00436	0.00490

TEST RUN NUMBER TWO

	Unmodified Sampler	Modified Sampler
Current (Knots)	-	2.5
Calibration Factor	4.0	3.0
Total Flow (Liters)	4080	1320
Plankton Catch (ML)	25	8
Plankton Density (ML/L)	0.00614	0.00606

TEST RUN NUMBER THREE

	Unmodified Sampler	Modified Sampler
Current (Knots)	-	3.0
Calibration Factor	4.0	3.2
Total Flow (Liters)	3200	1535
Plankton Catch (ML)	14	7
Plankton Density (ML/L)	0.00438	0.00456

TEST RUN NUMBER FOUR

	Unmodified Sampler	Modified Sampler
Current (Knots)	-	0.0
Calibration Factor	4.0	2.0
Total Flow (Liters)	2320	1040
Plankton Catch (ML)	10	4
Plankton Density (ML/L)	0.00431	0.00385

TEST RUN NUMBER FIVE

	Unmodified Sampler	Modified Sampler
Current (Knots)	-	0.0
Calibration Factor	4.0	2.0
Total Flow (Liters)	2408	1050
Plankton Catch (ML)	9	4
Plankton Density (ML/L)	0.00362	0.00381

UNMODIFIED SAMPLER ADJACENT TO PIER AREA

	Test Run Number Six	Test Number Seven
Current (Knots)	0.0	0.0
Calibration Factor	2.0	2.0
Total Flow (Liters)	1012	996
Plankton Catch (ML)	4	3
Plankton Density (ML/L)	0.00395	0.00308

A comparison of plankton densities determined in each phase of a particular run indicates that the modified sampler is capable of collecting plankton as effectively, if not as abundantly, as the normally operated device. It is recognized that five decimal point accuracy in computing density is not valid for values of water and plankton volume which are necessarily to some degree inaccurate. Even though density values must therefore be considered as qualitative rather than quantitative, it is felt that their comparison is valid in arriving at a determination of modification effectiveness.

Of further interest is the composition of the comparative samples. In order to determine any significant differences in the type of plankton obtained by the two methods, samples were investigated and counts made of the various plankton in each. The results of this investigation, expressed as a percentage of the total sample, are as follows:

TEST RUN NUMBER ONE

Plankton Type	Unmodified Sampler	Modified Sampler
Medusae	2	3
Comb Jellies	3	5
Arrow Worms	20	21
Copepods	21	26
Mysids	12	12
Tunicate larvae	19	18
Annelid Worm larvae	1	0
Brachyuran Larvae	21	14
Fish larvae	1	1

TEST RUN NUMBER TWO

Plankton Type	Unmodified Sampler	Modified Sampler
Medusae	3	4
Comb Jellies	3	4
Arrow Worms	20	24
Copepods	11	12

TEST RUN NUMBER TWO (CONT.)

Mysids	11	12
Tunicate larvae	18	13
Annelid Worm larvae	1	1
Brachyuran larvae	24	20
Fish larvae	1	1

TEST RUN NUMBER THREE

Plankton Type	Unmodified Sampler	Modified Sampler
Medusae	3	6
Comb Jellies	4	4
Arrow Worms	18	17
Copepods	23	31
Mysids	18	9
Tunicate larvae	9	19
Annelid Worm larvae	1	3
Brachyuran larvae	23	8
Fish larvae	1	3

TEST RUN NUMBER FOUR

Plankton Type	Unmodified Sampler	Modified Sampler
Medusae	1	2
Comb Jellies	3	4
Arrow Worms	5	4

TEST RUN NUMBER FOUR (CONT.)

Copepods	18	21
Mysids	38	32
Tunicate larvae	23	18
Annelid Worm larvae	0	0
Brachyuran larvae	11	17
Fish larvae	1	2

TEST RUN NUMBER FIVE

Plankton Type	Unmodified Sampler	Modified Sampler
Medusae	8	3
Comb Jellies	0	0
Arrow Worms	7	2
Copepods	30	26
Mysids	19	29
Tunicate larvae	21	15
Annelid Worm larvae	0	0
Brachyuran larvae	14	25
Fish larvae	1	0

UNMODIFIED SAMPLER ADJACENT TO PIER AREA

Plankton Type	Test Run Number Six	Test Run Number Seven
Medusae	7	9
Comb Jellies	0	0

PIER AREA (CONT.)

Arrow Worms	0	4
Copepods	18	14
Mysids	20	14
Tunicate larvae	14	50
Annelid Worm larvae	0	0
Brachyuran larvae	41	9
Fish larvae	0	0

These computations reveal that plankton types collected during each test run by the unmodified sampler were also entrapped by the modified device and, with but one notable exception, in approximately the same relative quantities. The sparcity of Brachyuran larvae collected by the modified sampler during test run number three is a unique anomoly and is attributed to the chance distribution of this animal in the test area. Test runs number six and seven were conducted with the modified sampler in the pier area of Monterey Bay. These two runs occurred within a thirty minute interval and give some indication of plankton patchiness, at least in the immediate area.

It was further noted that plankton gathered by the modified sampler were delivered to the net in excellent condition. Although the powered impeller operates at high speed out of the water, its rotation under water is sufficiently slow to avoid damaging the sample.

5. Operation and Maintenance.

Since the modification package adds an additional eight pounds to the weight placed on the supporting wire, there is a tendency for the assembly to bend the wire out of the vertical at the point of attachment. It is for this reason that a floatation device has been added to the rudder. In practice, it has been found that a fifty pound weight attached to the end of the wire provides sufficient tension to keep the wire vertical and, in fact, obviates the need for a float.

The modified sampler is easily assembled and operated by one person. First, the locking rod is attached to hold the body horizontal. The body extension, with drive motor and rudder attached, should now be affixed to the sampler body. The plankton net is then secured to the after end of the body extension using the standard hose clamp. The net is supported in the usual manner by the support rod which is now attached to the side of the motor body. The sampler is now fully assembled (Figure 24).

The first step in preparing the motor for a run is to set the sampler gate in the half-cocked (open) position. Next, rotate the gear train by hand while pressing on the cocking assist plunger until the cocking plunger moves all the way down to engage gear D. Push the trigger rod back until it is over the top of the cocking plunger. Release the cocking assist plunger and complete the normal cocking of the gate. The sampler is now fully cocked. As a final step, lift the stop plunger, pull the stop rod forward and release the stop plunger. The motor is now ready for winding. Using a device, such as the 5/8 inch socket previously described, fully wind the power spring. Fourteen full turns is the maximum stress the spring will tolerate and, due to the dimensions of the spring, an unusual amount of effort will be required to exceed this limit. Although the drive motor is capable of withstanding the high speed it would encounter if it were allowed to operate out of the water, it is recommended that the winding operation be conducted with the assembly mounted on the wire. Thus, in the event of accidental triggering, the sampler could be quickly lowered below the surface where the motor will operate at a reduced speed. However, the motor can be safely braked by pressing on the cocking assist plunger or actuating the trigger mechanism.

Mounting on the wire, lowering to depth, starting, stopping and retrieval procedures are the same as with the basic Clarke-Bumpus sampler.

Since the frame of the basic instrument has not been altered, the self-release of messengers is incorporated in the modified configuration and, therefore, operation in tandem is possible. The modified sampler can also be utilized in conjunction with Nansen bottles.

If the sampler is to be operated by towing, removal of the body extension and locking rod renders the sampler fully ready for normal use. Operations conducted with the altered instrument have shown that the alterations in no way affect performance under tow.

After recovery, the routine maintenance afforded the basic sampler should be applied to the modification assembly. A thorough rinsing with fresh water should suffice to clear the apparatus of most contaminants.

Periodic total immersion in a mixture of kerosene and light lubricating oil will enhance the machine's operability. The drive motor has been designed for easy removal from the body extension in order to facilitate such a cleaning procedure. Access ports have been provided in the top of the spring drum to permit free passage of cleansing agents. An additional feature of the motor design is its easy disassembly to permit periodic removal of the drum in order that its interior may be inspected for contaminants and the spring checked for signs of wear.

6. Conclusions and Acknowledgements.

The modification to the Clarke-Bumpus plankton sampler described herein has fulfilled its original design specifications in that it is of relatively simple construction, is easily assembled and operated and does not prevent the sampler from being used in its normal towed manner. It has been found to operate in accordance with expectations with regard to filtering capacity and effectiveness in collecting samples.

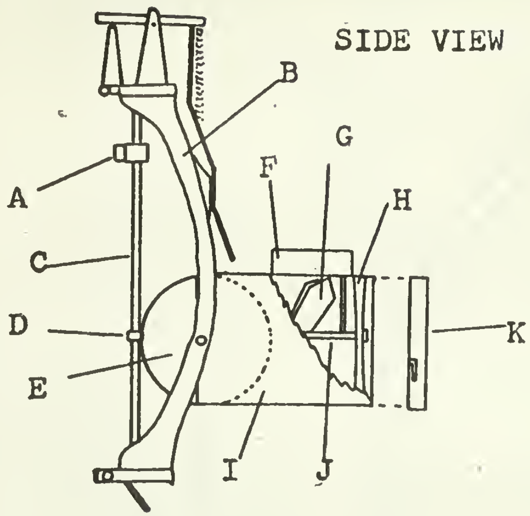
The prototype model has been constructed of materials not expected to appear in a production instrument. Since non-corrosive materials were not readily available during the alloted construction period, parts have been machined of aluminum, steel and brass. In spite of the obvious shortcomings of this combination, the machine has remained in excellent material condition with the benefit of reasonable care. A production model would, of course, incorporate non-corrosive and platable materials thus reducing maintenance requirements to a level comparable with the basic sampler. Power springs are available in a variety of non-corrosive materials, several of which possess tensile properties equal to those of the clock spring steel used in the prototype. [6] The ball bearings used in the original model are also available in non-corrosive material. It is felt, however, that replacement with nylon bushings would reduce cost and maintenance. Any reduction in motor output caused by increased friction could be compensated for by installing a larger power spring. The drive motor assembly has been designed to allow an increase in drum diameter of up to one inch thereby permitting a measure of flexibility in power selection.

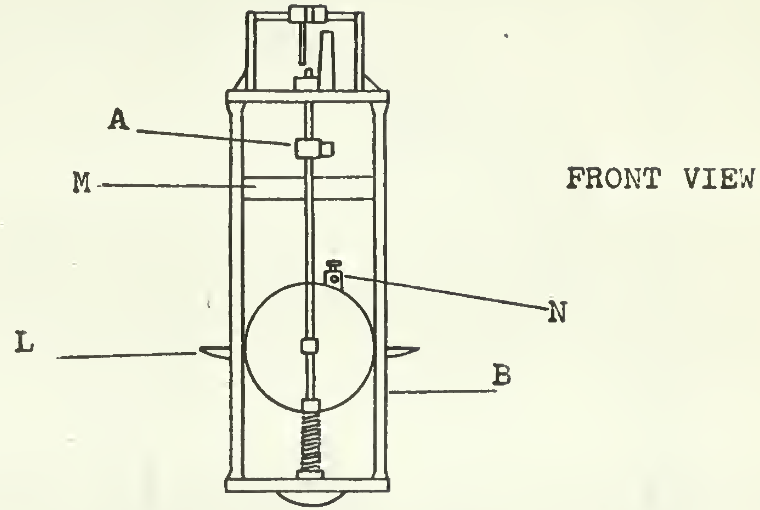
The primary shortcoming of the modification is the necessity of determining the current at the point of operation. Fortunately, knowledge of current speed alone is required and this simplifies matters somewhat, at least when using the Ekman current meter. A further simplification is presently being contemplated which would incorporate a small current meter integral with the modification package. Such an alteration appears entirely feasible and would improve operability.

Scaling up of the modification to make it compatible with the enlarged sampler described by Paquette and Scott [4] is not considered practical due to the resultant size and weight of the assembly.

The encouragement and assistance of Professors E. C. Haderlie, C. L. Taylor, T. Green III and W. W. Denner of the United States Naval Postgraduate School has been a significant factor in the development and execution of this project. Their interest and aid is gratefully acknowledged. Mr. M. K. Andrew, Department of Physics, United States Naval

Postgraduate School, has been of special assistance in providing both materials and technical advice. Particular acknowledgement is extended to W. H. Harris, MR1, whose infinite skill with machine and metal has produced the prototype model.





KEY

A - Motor control plate	H - After Impeller Shaft Support
B - Frame	I - Body
C - Gate Release Rod	J - Impeller Shaft
D - Gate Release Catch	K - Net Adapter Ring
E - Gate	L - Vane
F - Revolutions Counter	M - Frame Cross-Support Plate
G - Impeller	N - Net Support Rod Securing Post

FIGURE 1

SIMPLIFIED VIEWS OF THE CLARKE-BUMPUS PLANKTON SAMPLER
WITH MOTOR CONTROL PLATE (A)

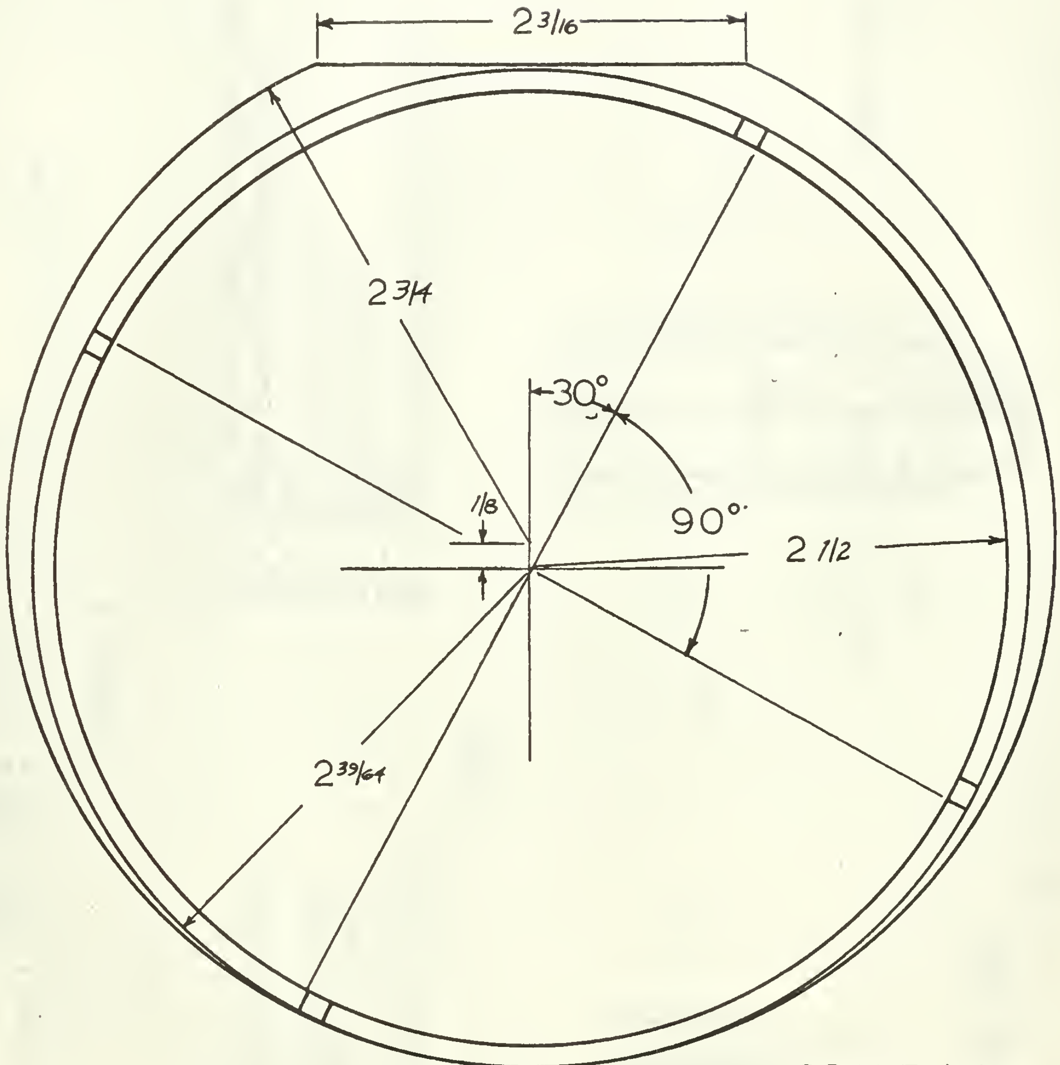


FIGURE 2

BODY EXTENSION
(FWD END)

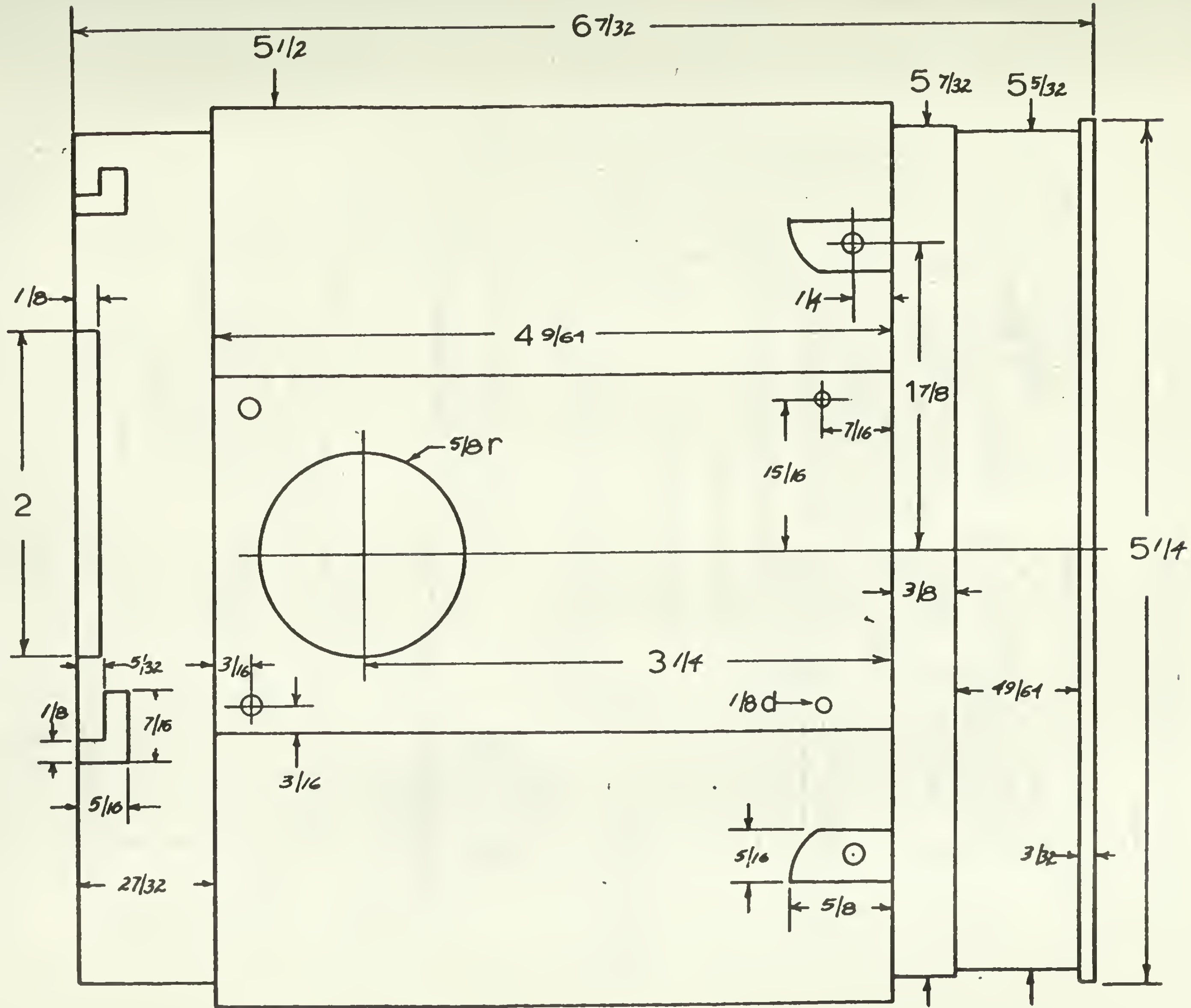


FIGURE 3

BODY EXTENSION (TOP VIEW)

SCALE 1:1
(INCHES)

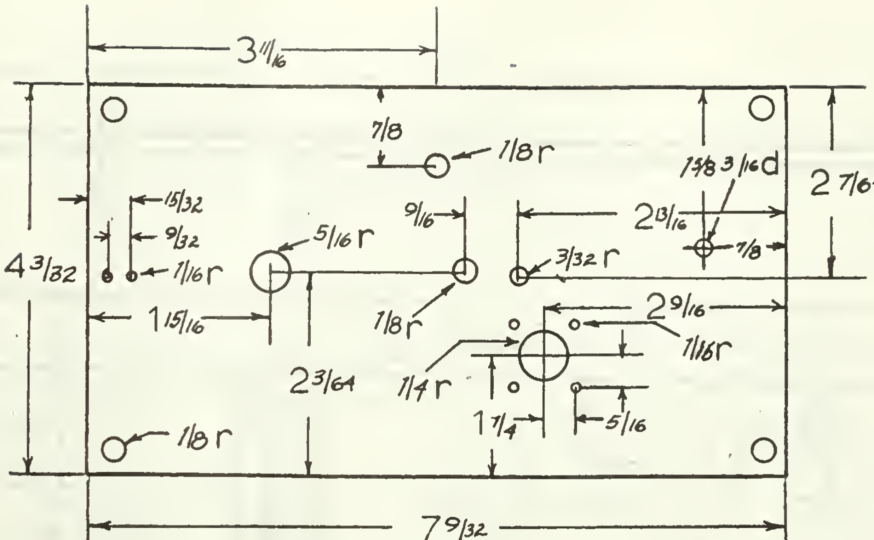
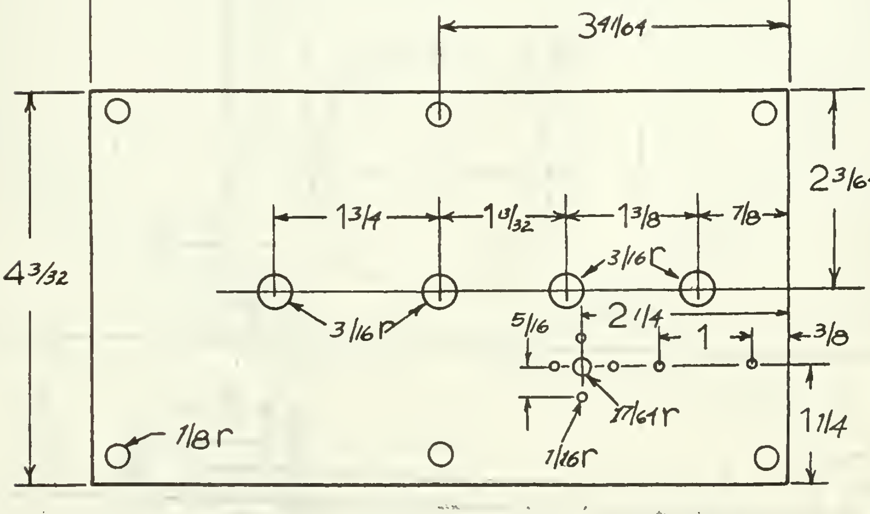


FIGURE 4

TOP PLATE

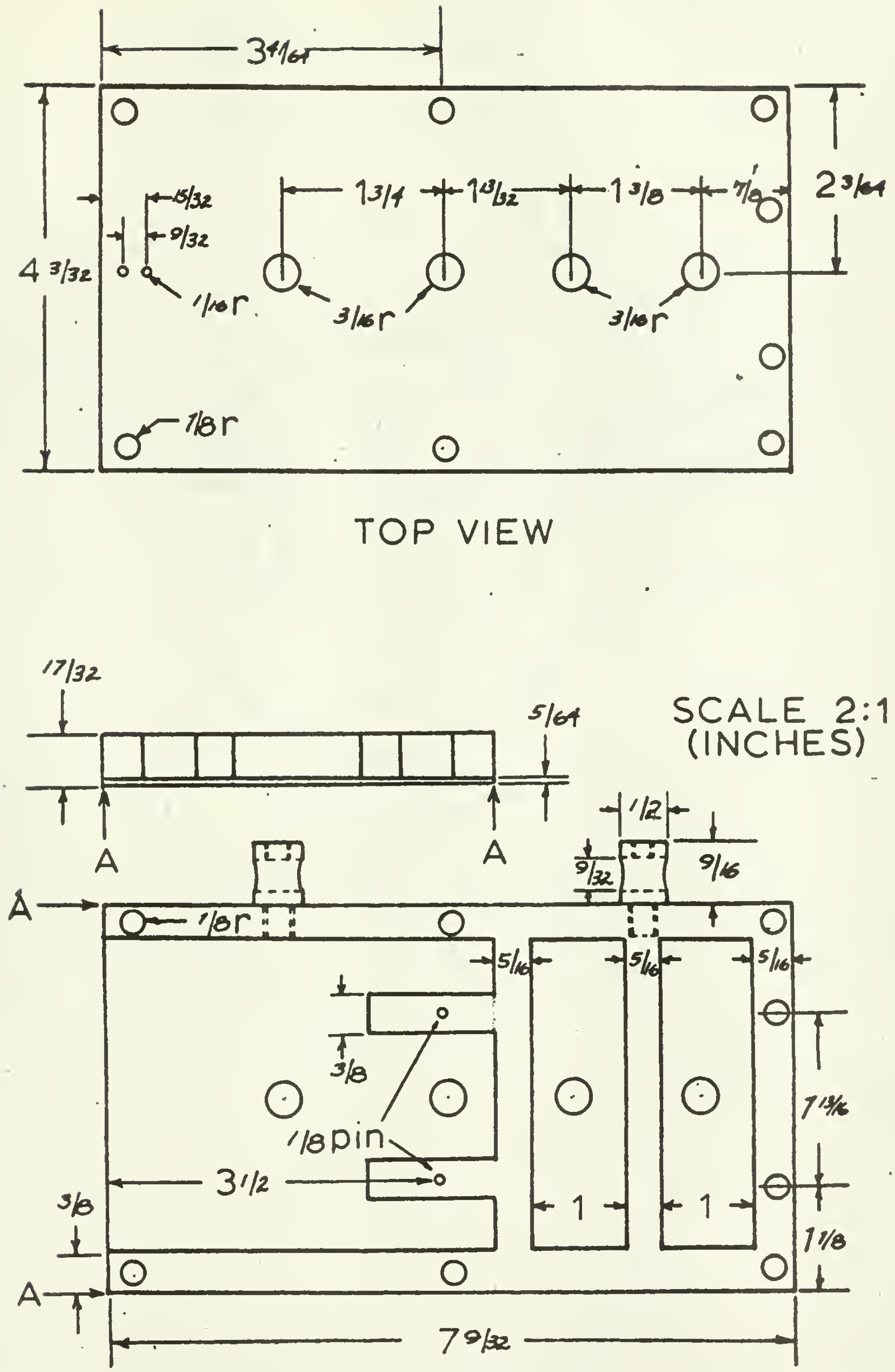


3/32 PLATE

FIGURE 5

MIDDLE PLATE

SCALE 2:1
(INCHES)



BOTTOM VIEW

FIGURE 6

BOTTOM PLATE

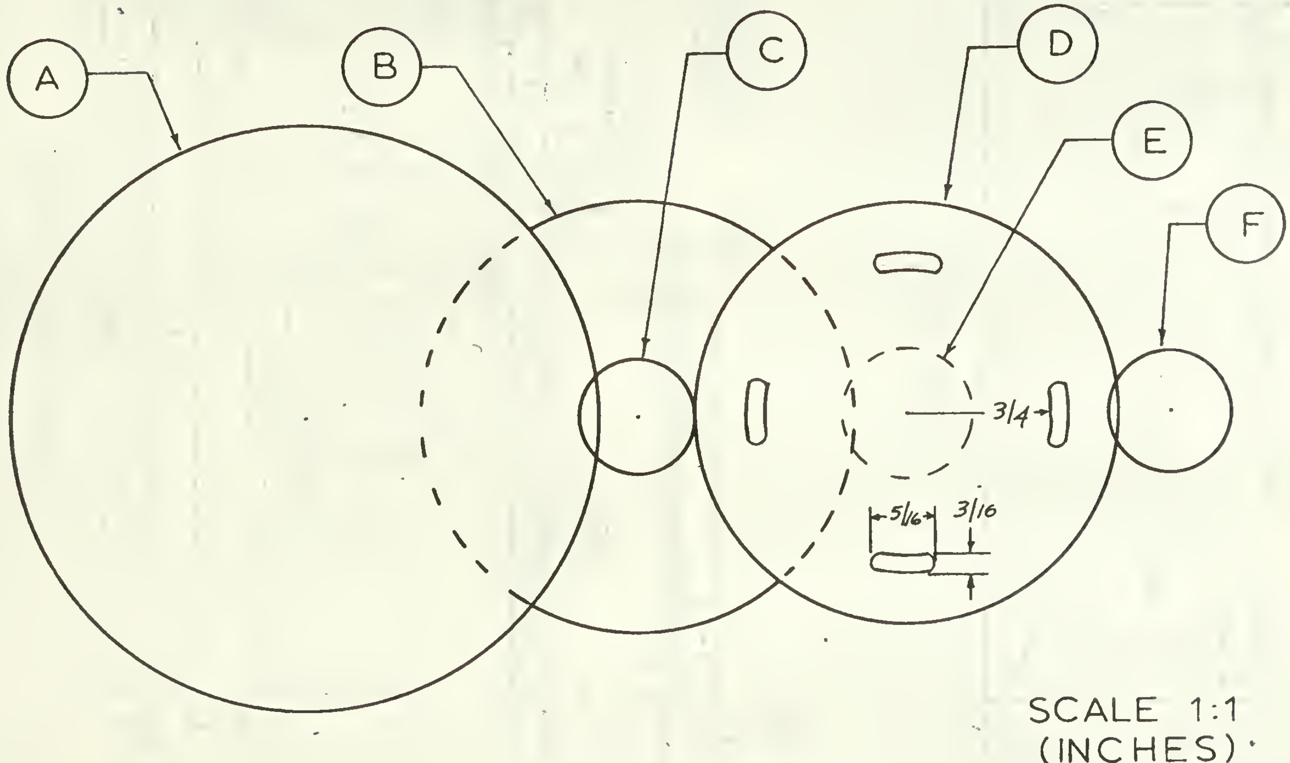


FIGURE 7

GEAR TRAIN

GEAR TRAIN DATA

Gear	Pitch Dia. (Inches)	No. of Teeth	Shaft Size (Inches)
A	3.000	96	0.2500
B	2.187	70	0.2500
C	0.500	16	0.2500
D	2.156	69	0.2500
E	0.531	17	0.2500
F	0.562	18	0.2500
Drive Shaft Miter	0.875	21	0.3125

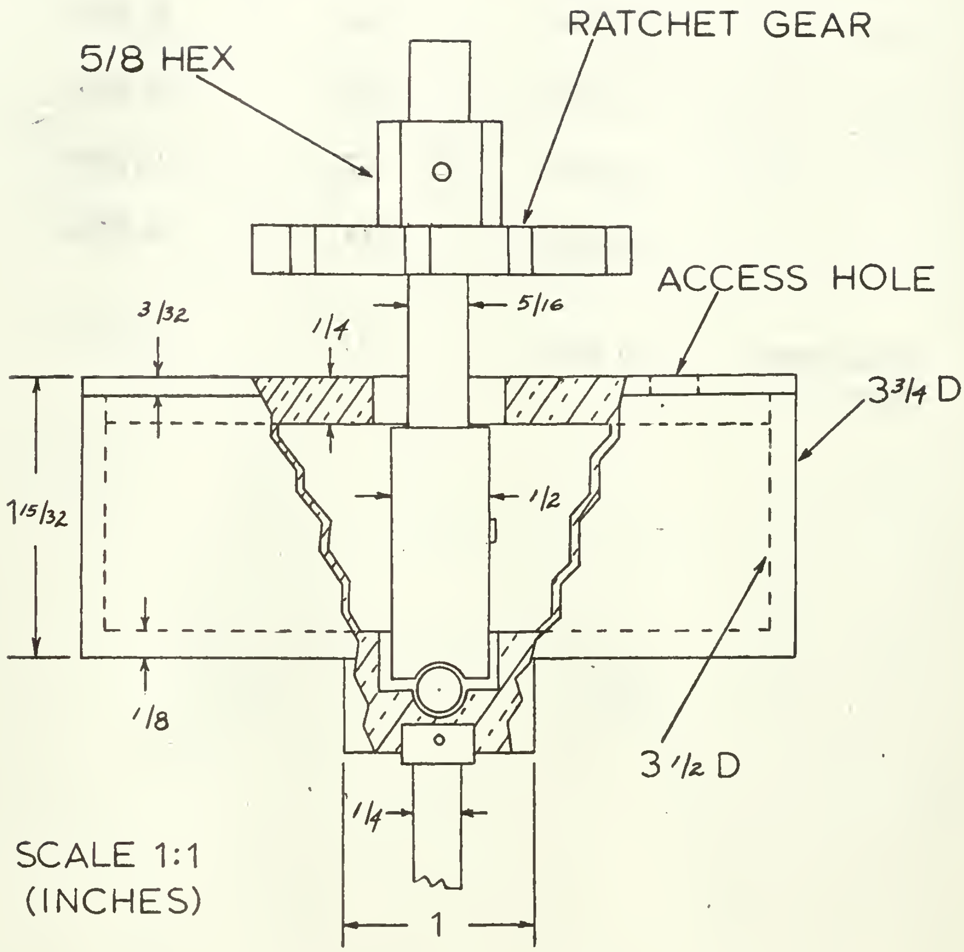
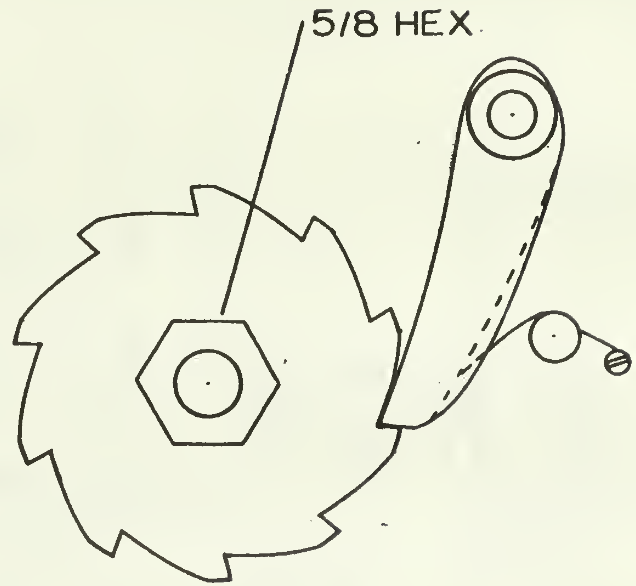


FIGURE 8

DRUM AND ARBOR



SCALE 1:1
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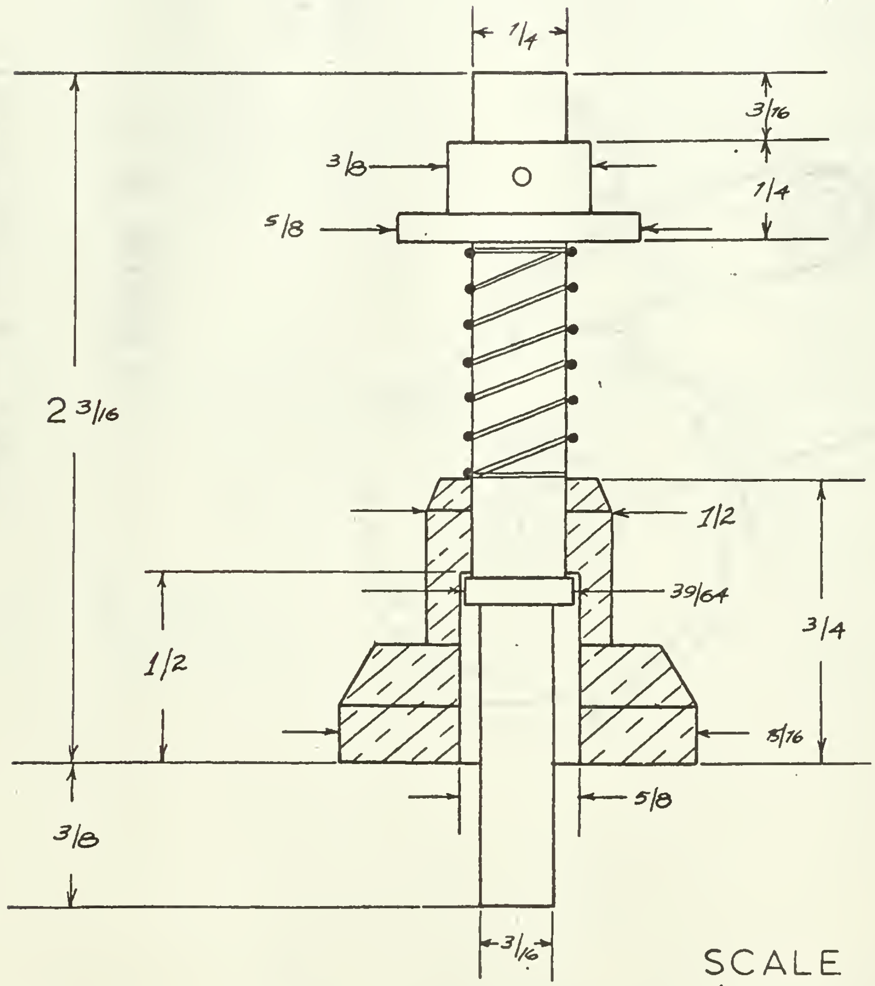
FIGURE 9

RATCHET MECHANISM

FIGURE 10



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COCKING PLUNGER

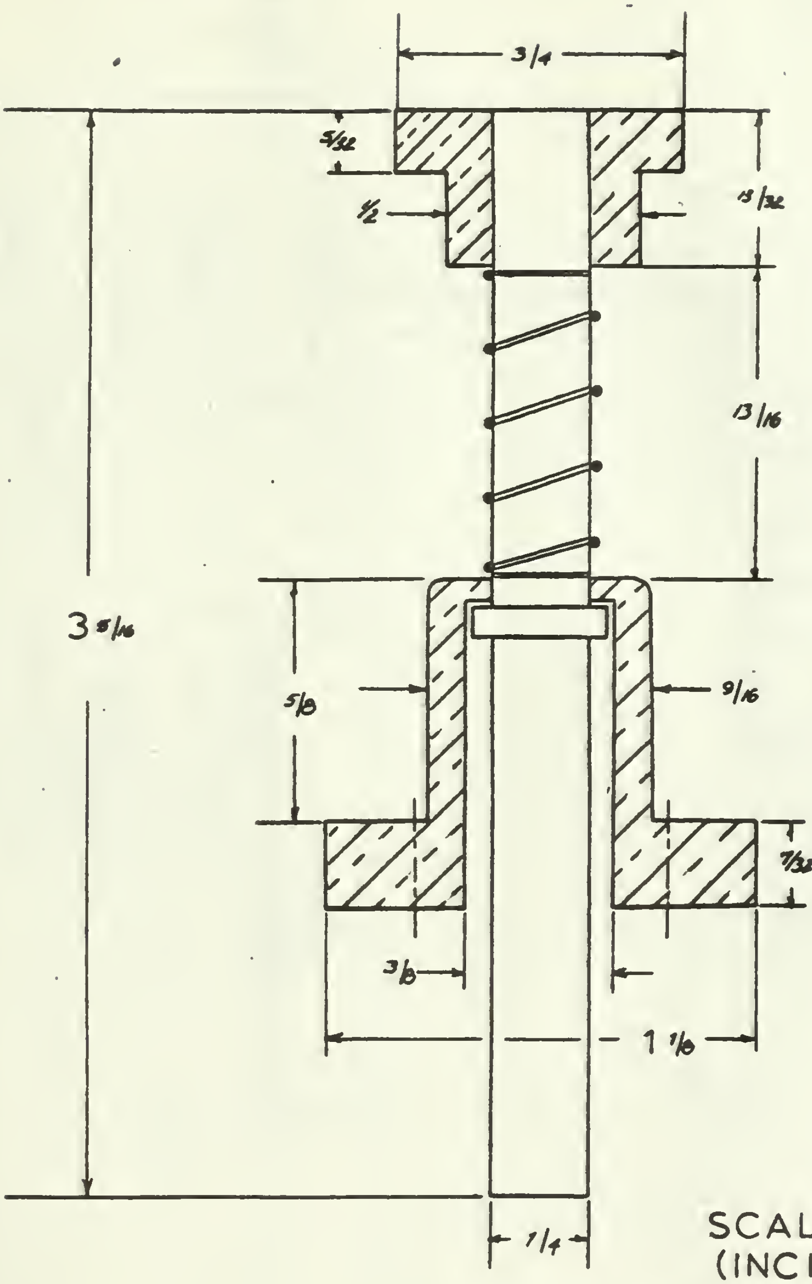

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FIGURE 11

COCKING ASSIST PLUNGER

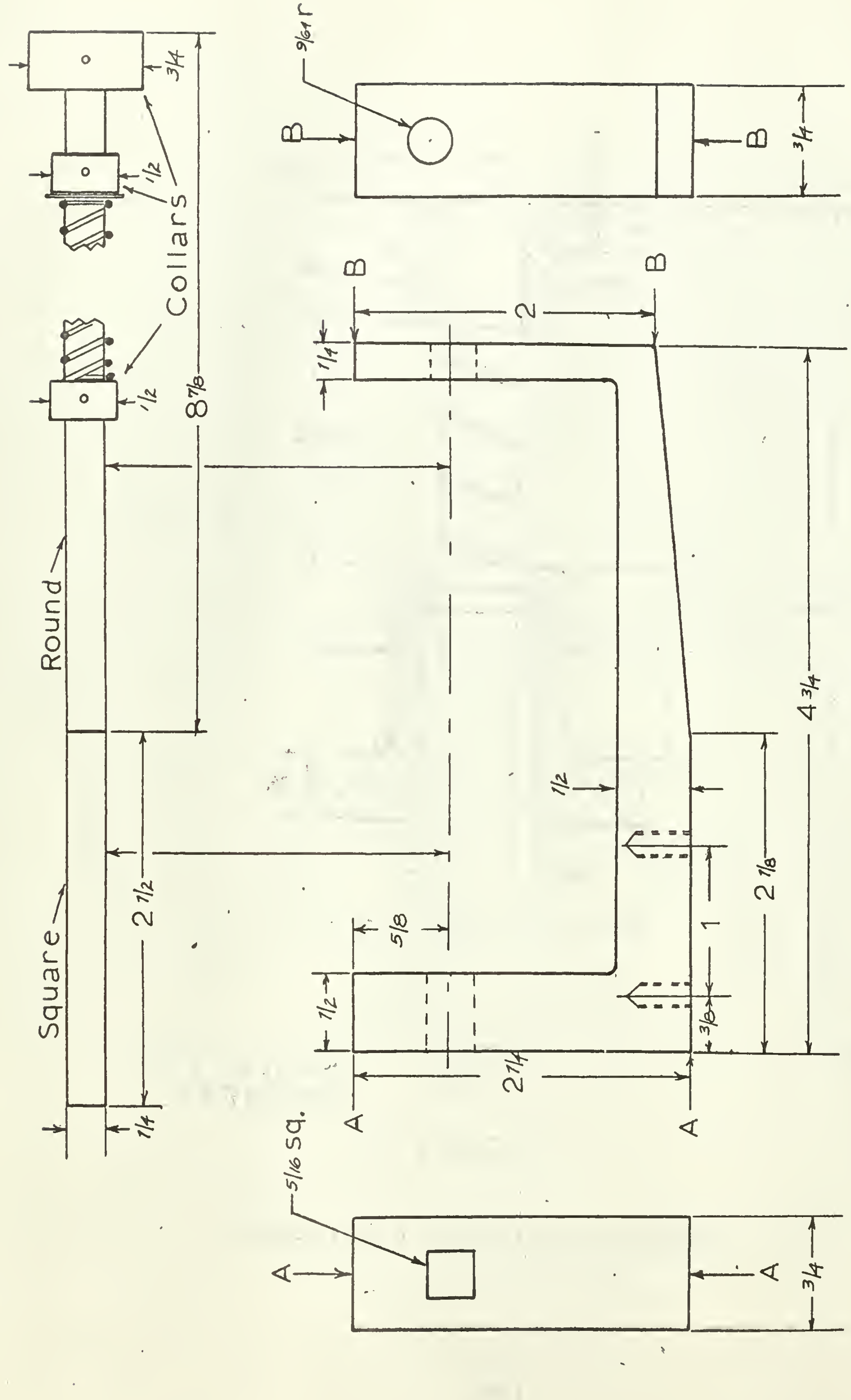

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FIGURE 12
TRIGGER MECHANISM

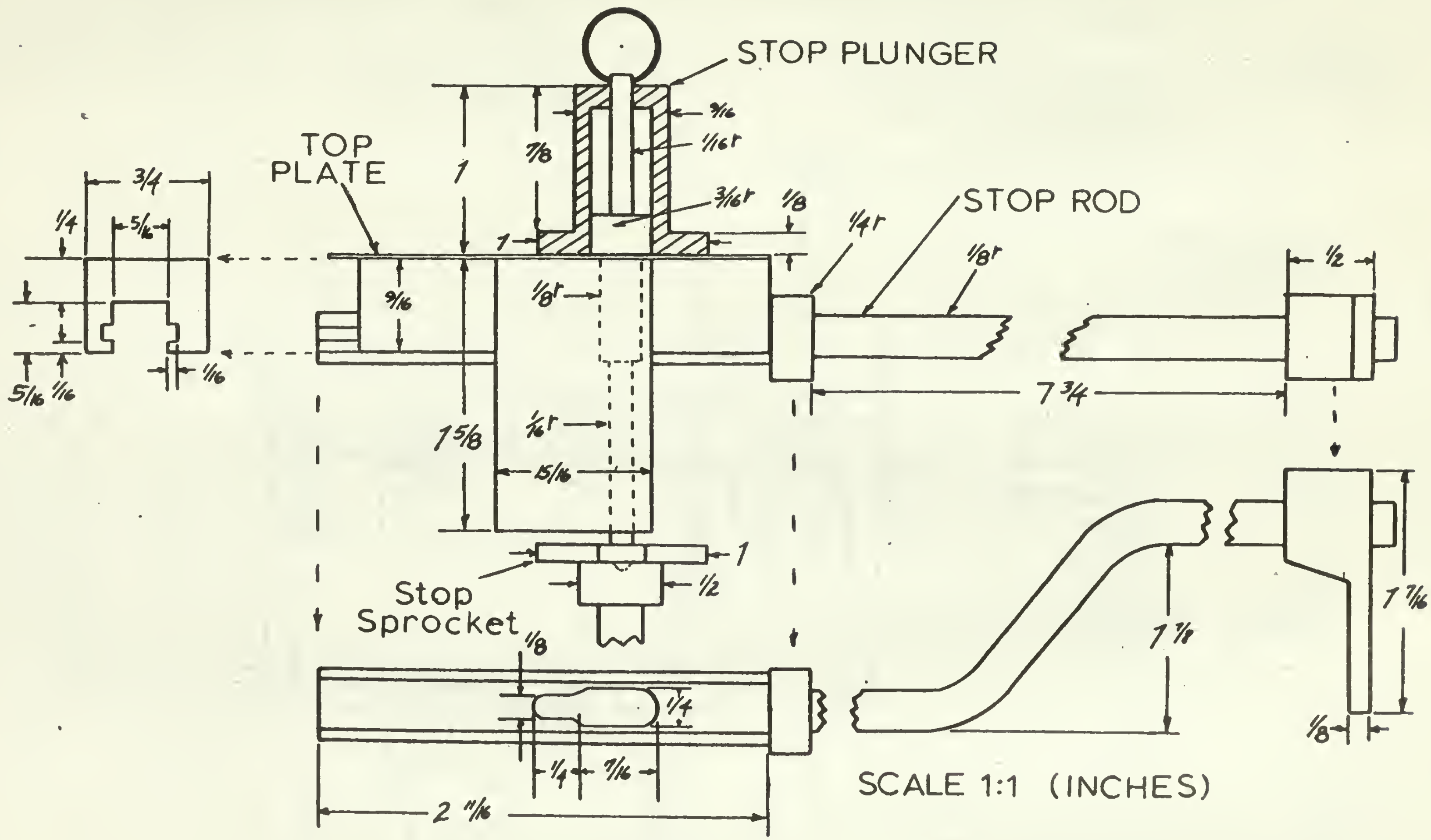
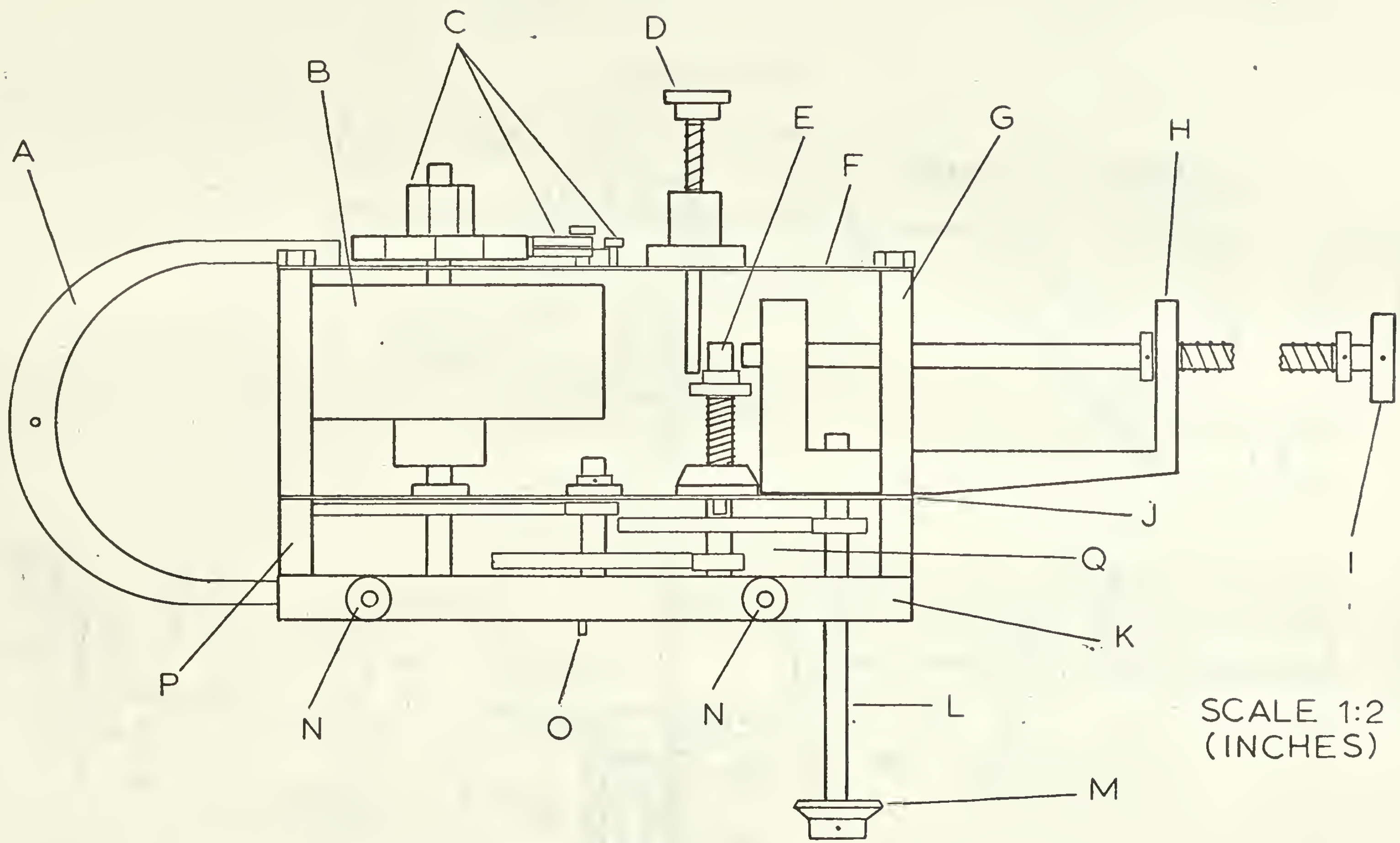


FIGURE 13

STOP MECHANISM



SCALE 1:2
(INCHES)

FIGURE 14

DRIVE MOTOR

PARTS LIST FOR FIGURE 14

Part	Description	See Figure
A	Rudder Mount	17
B	Spring Drum	8
C	Ratchet Mechanism	9
D	Cocking Assist Plunger	11
E	Cocking Plunger	10
F	Upper Plate	4
G	Upper Spacer Post	19
H	Trigger Mechanism	12
I	Trigger Stop Collar	12
J	Middle Plate	5
K	Bottom Plate	6
L	Drive Shaft	-
M	Output Gear	-
N	Support Post	19
O	Locator Pin	6
P	Lower Spacer Post	19
Q	Gear Train	7

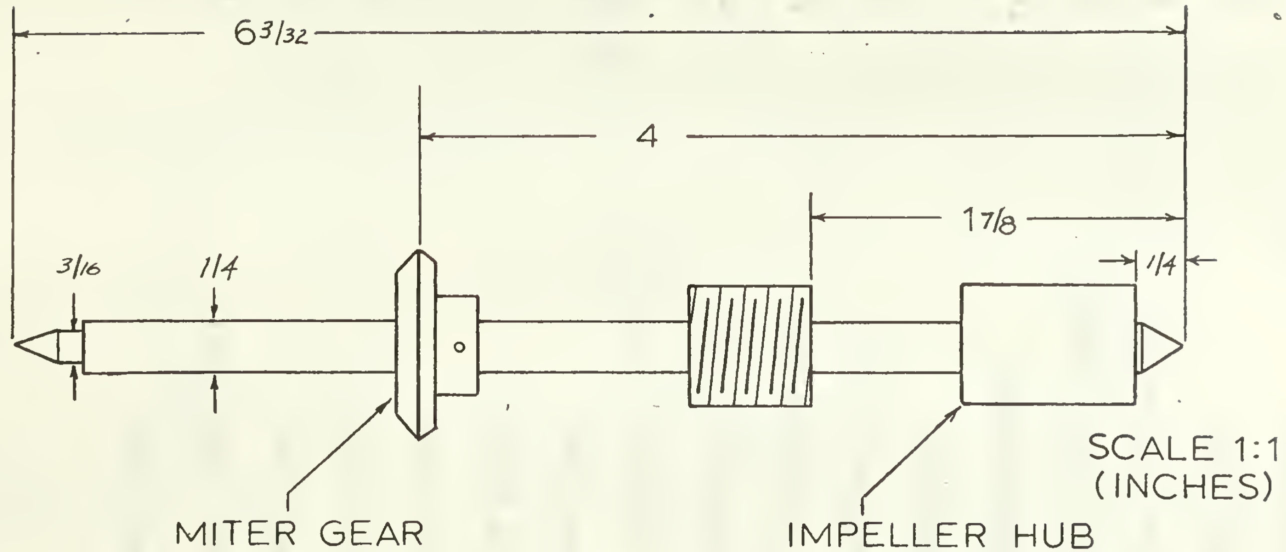


FIGURE 15

IMPELLER SHAFT

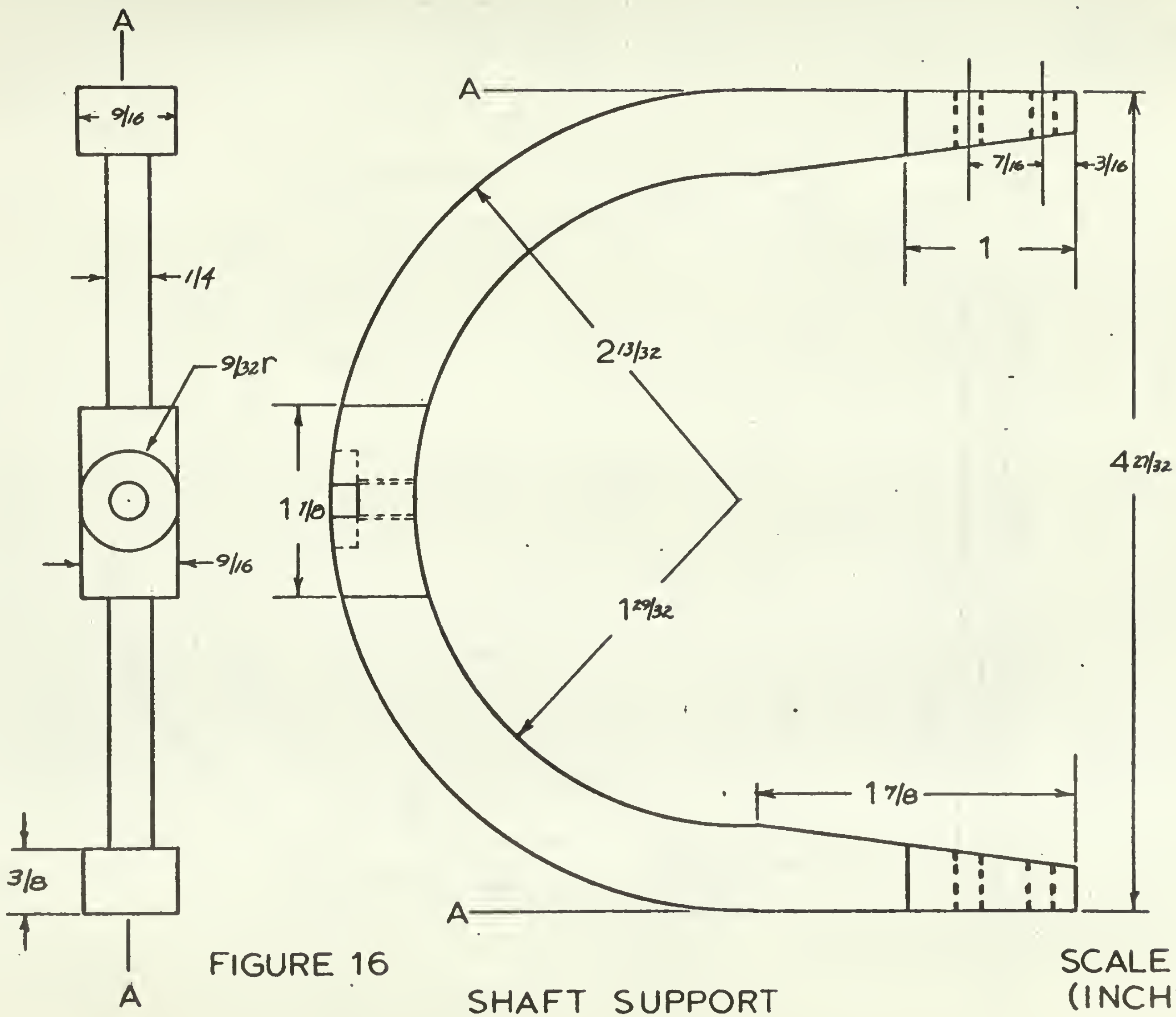


FIGURE 16

SHAFT SUPPORT

SCALE 1:1
(INCHES)

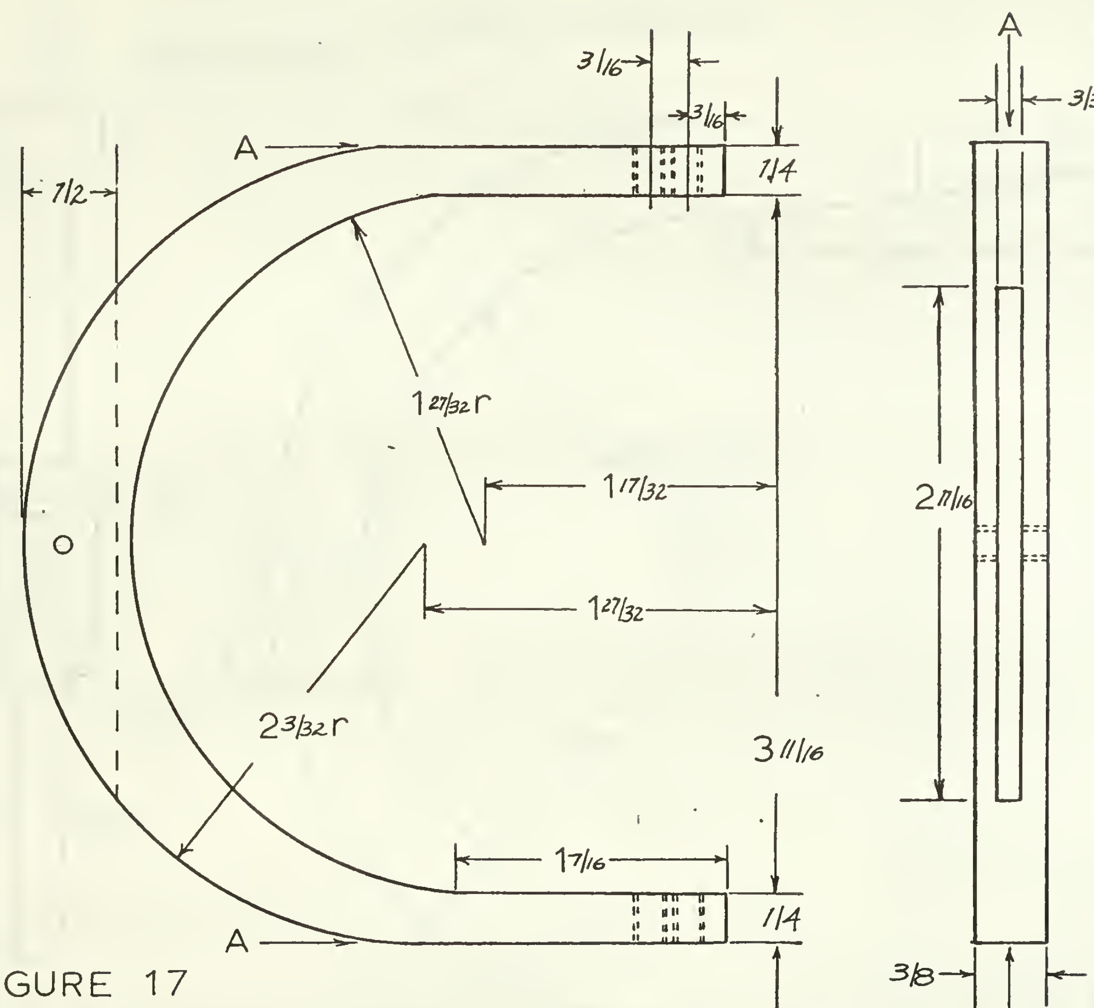
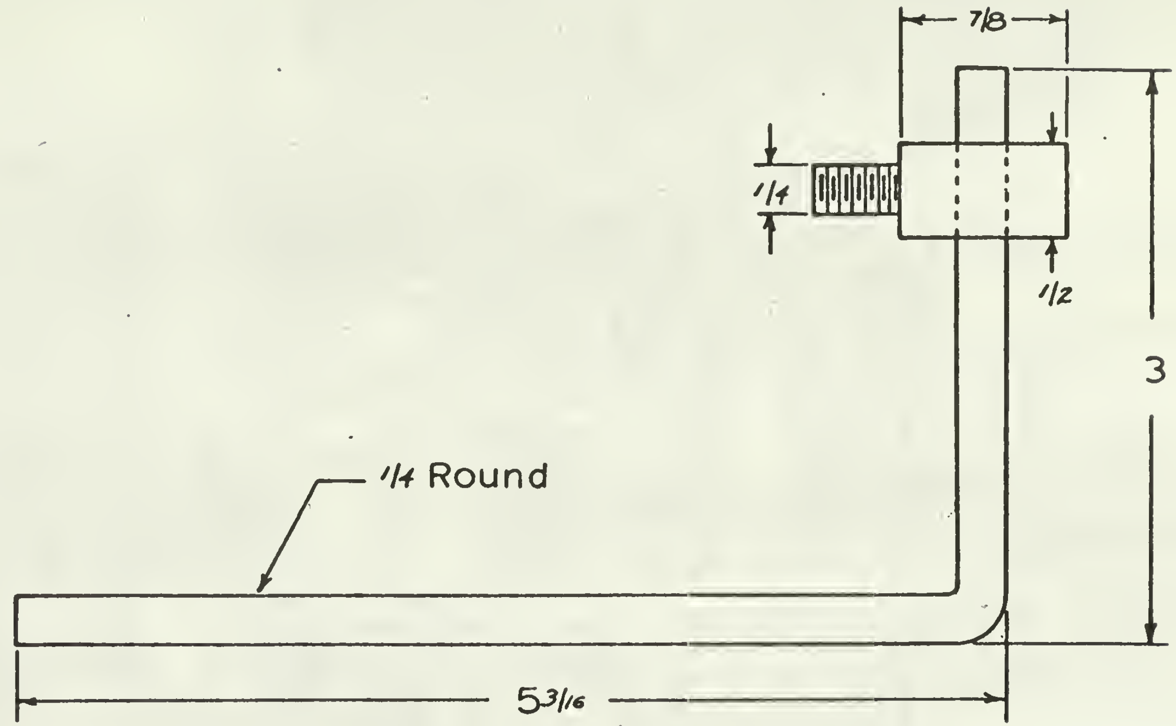


FIGURE 17

RUDDER MOUNT



SCALE 1:1
(INCHES)

FIGURE 18

LOCKING ROD

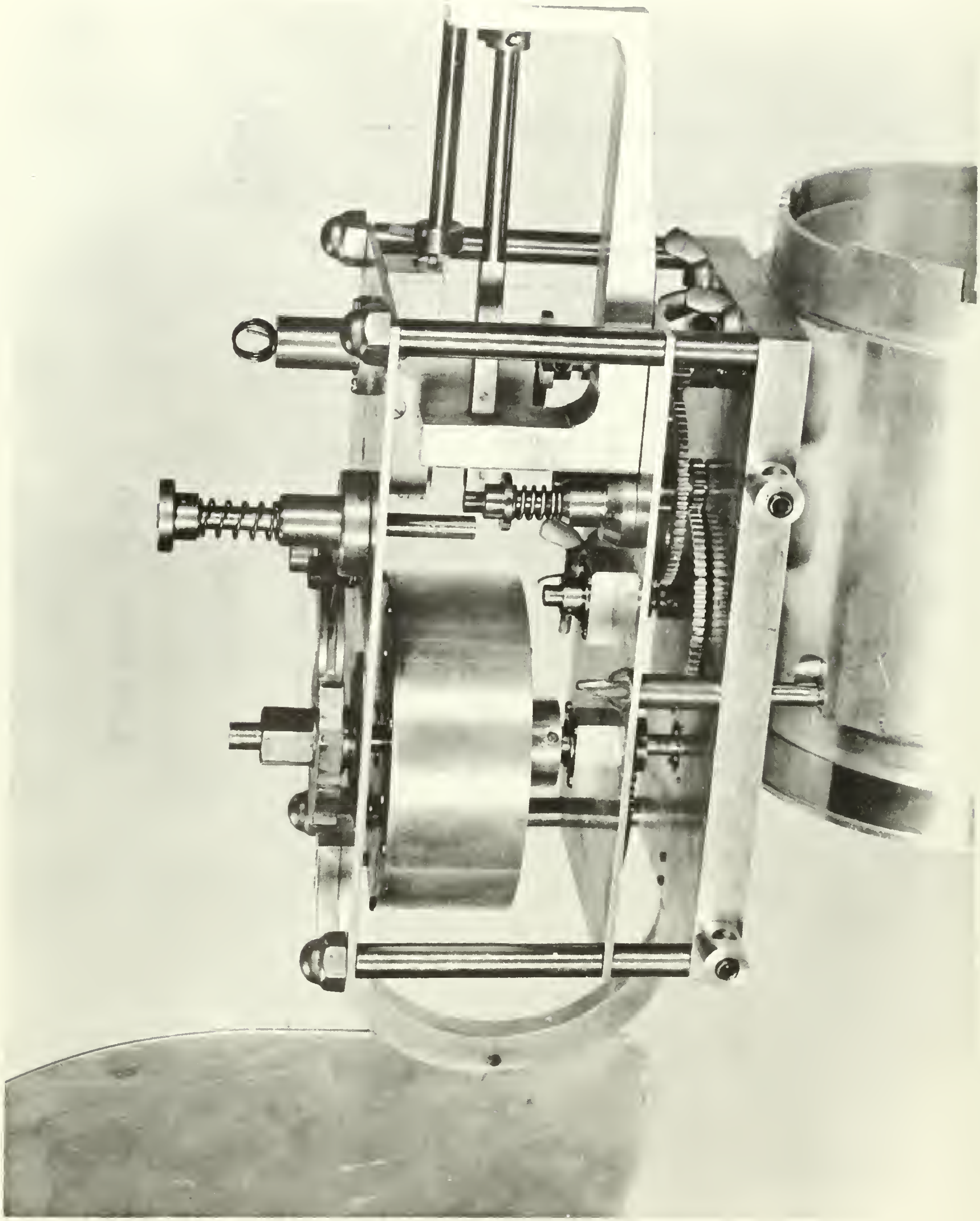


FIGURE 19 DRIVE MOTOR

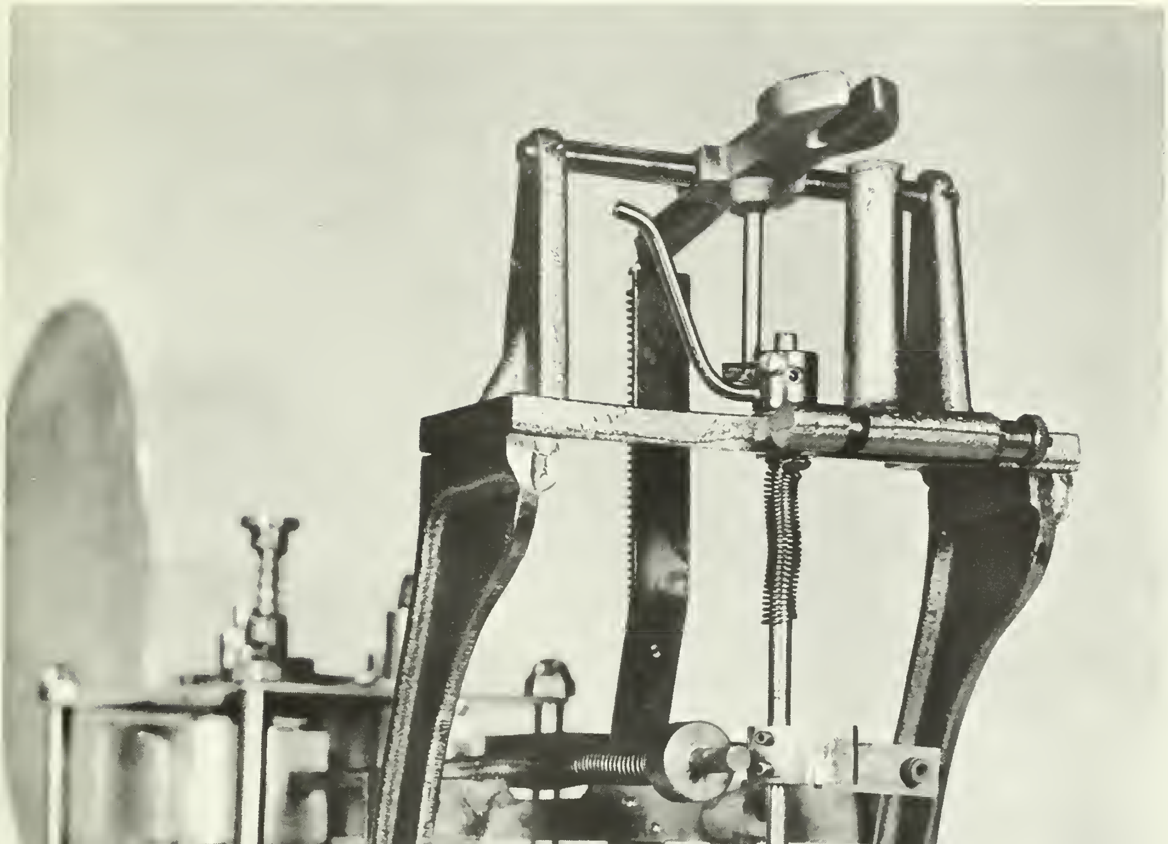


FIGURE 20

FRAME ASSEMBLY AND TRIGGER ROD

FIGURE 21

ALTERED CLARKE - BUMPUS SAMPLER

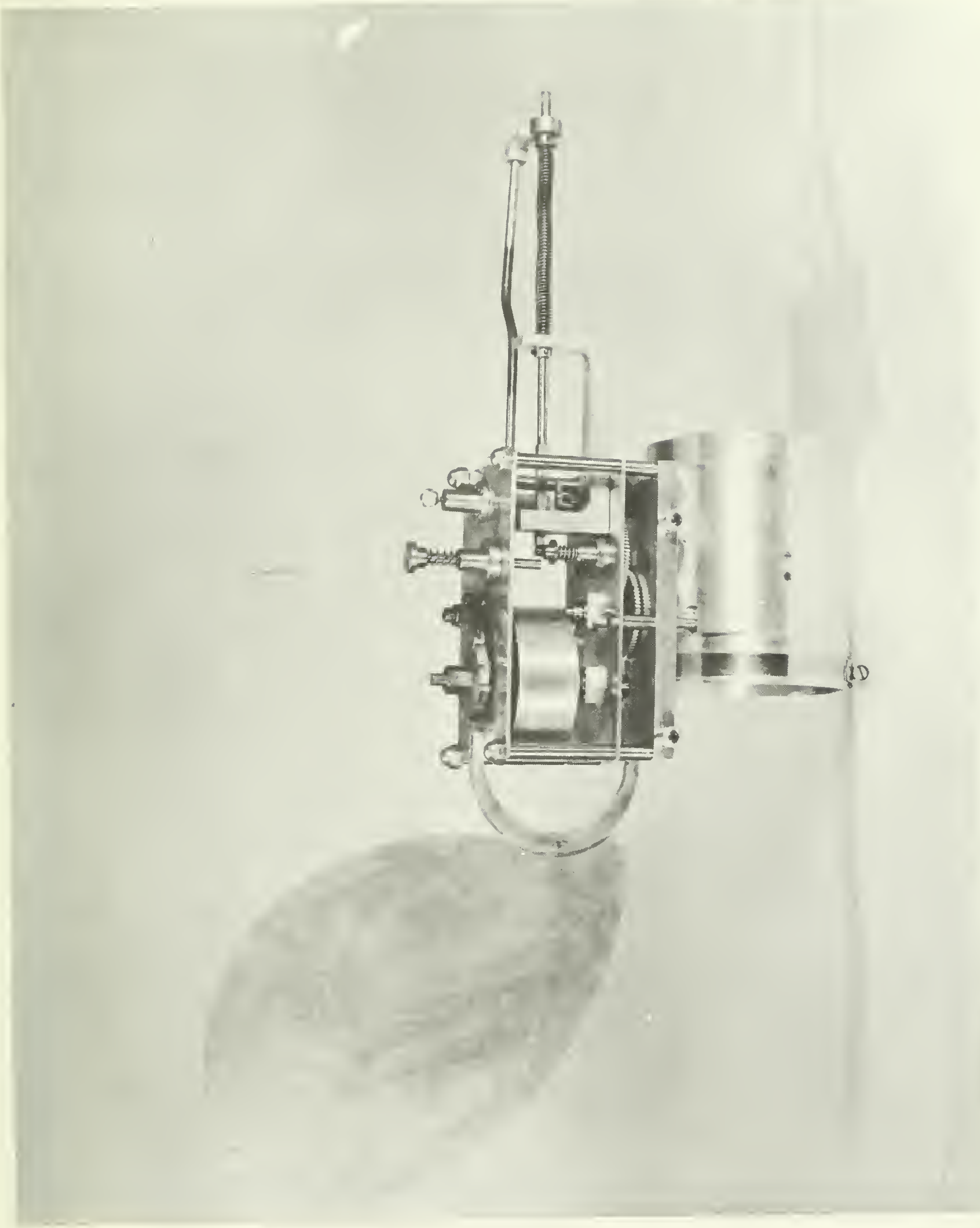


FIGURE 22
MODIFICATION ASSEMBLY (RIGHT VIEW)

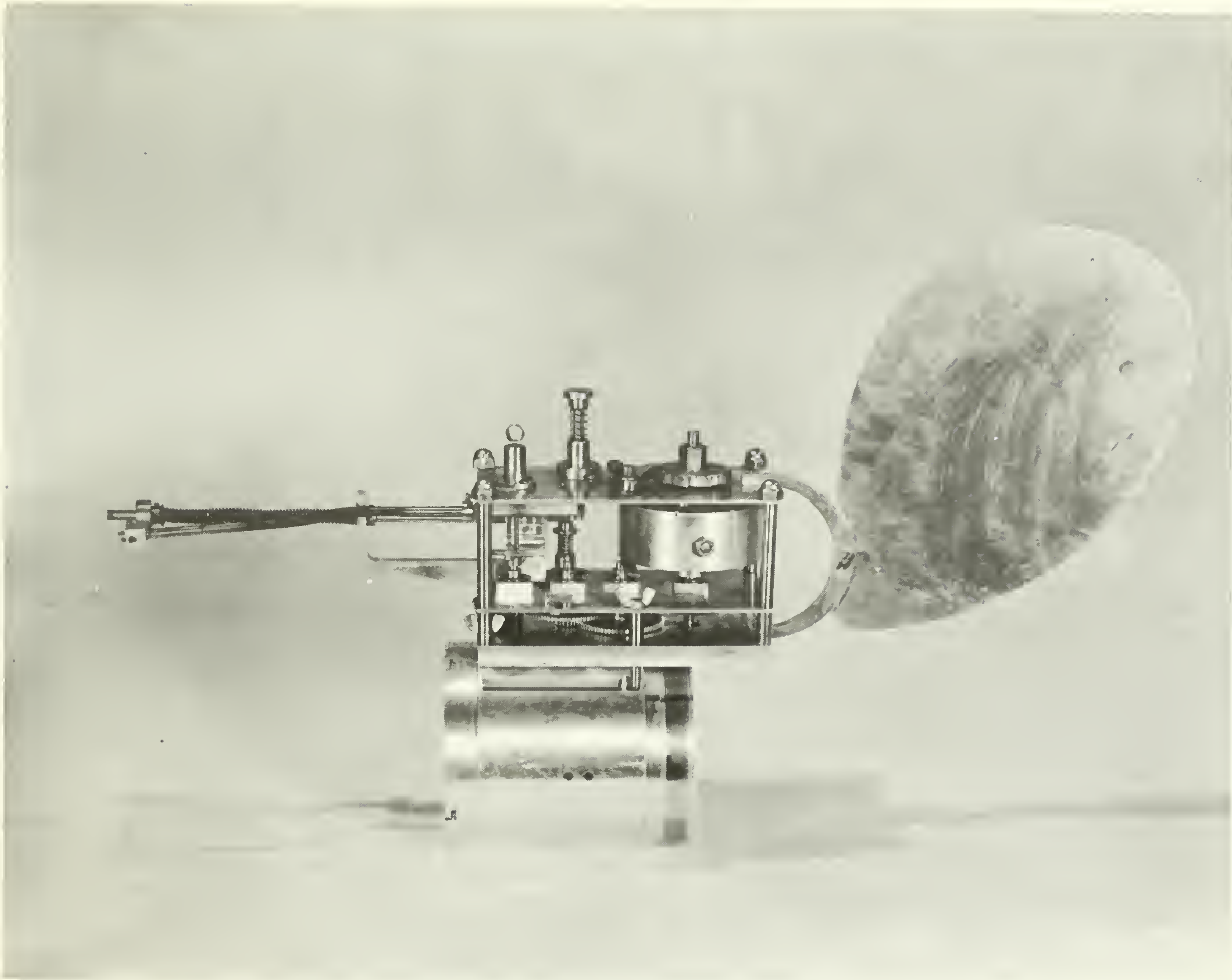


FIGURE 23
MODIFICATION ASSEMBLY (LEFT VIEW)

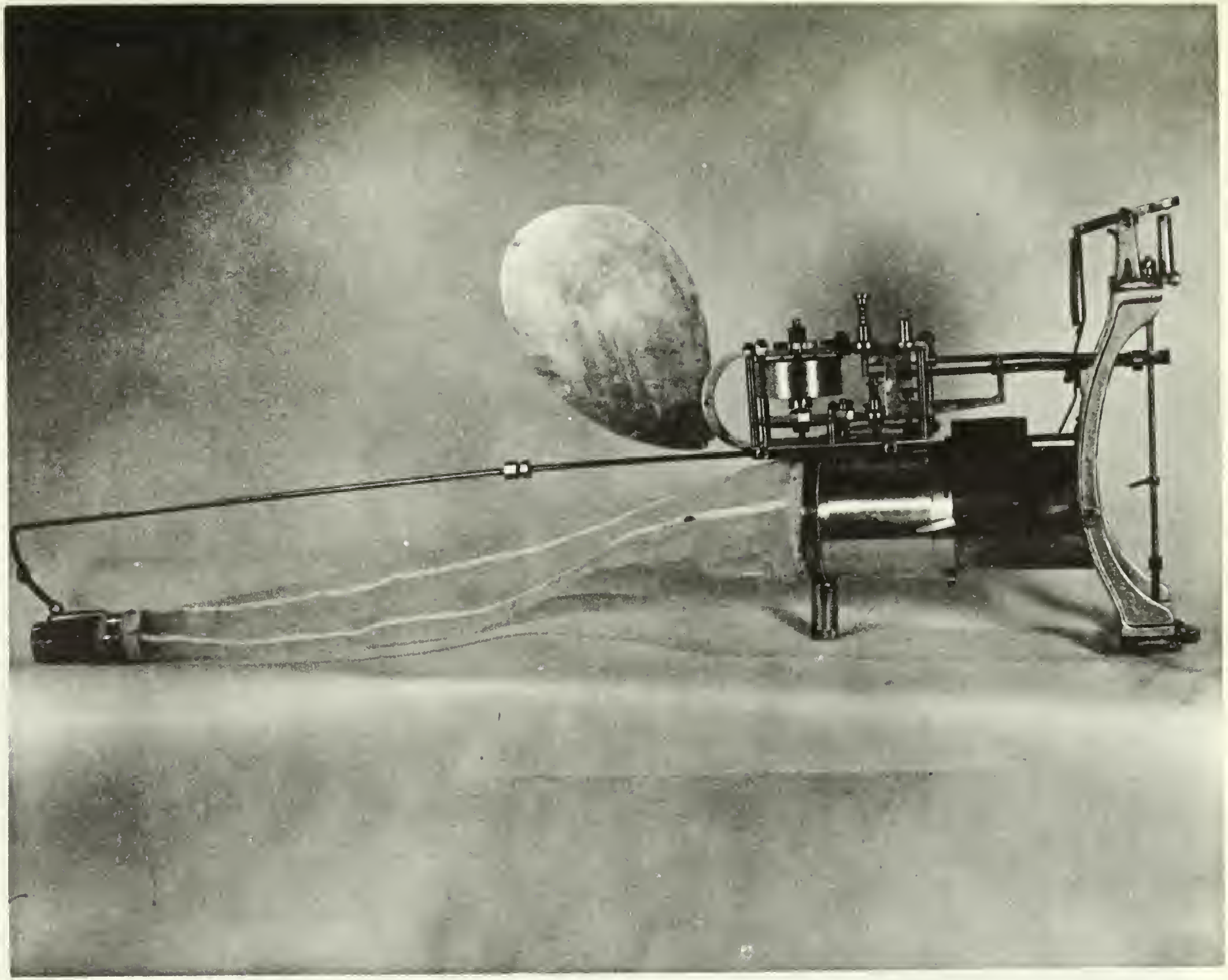


FIGURE 24

ASSEMBLED SAMPLER WITH MODIFICATION

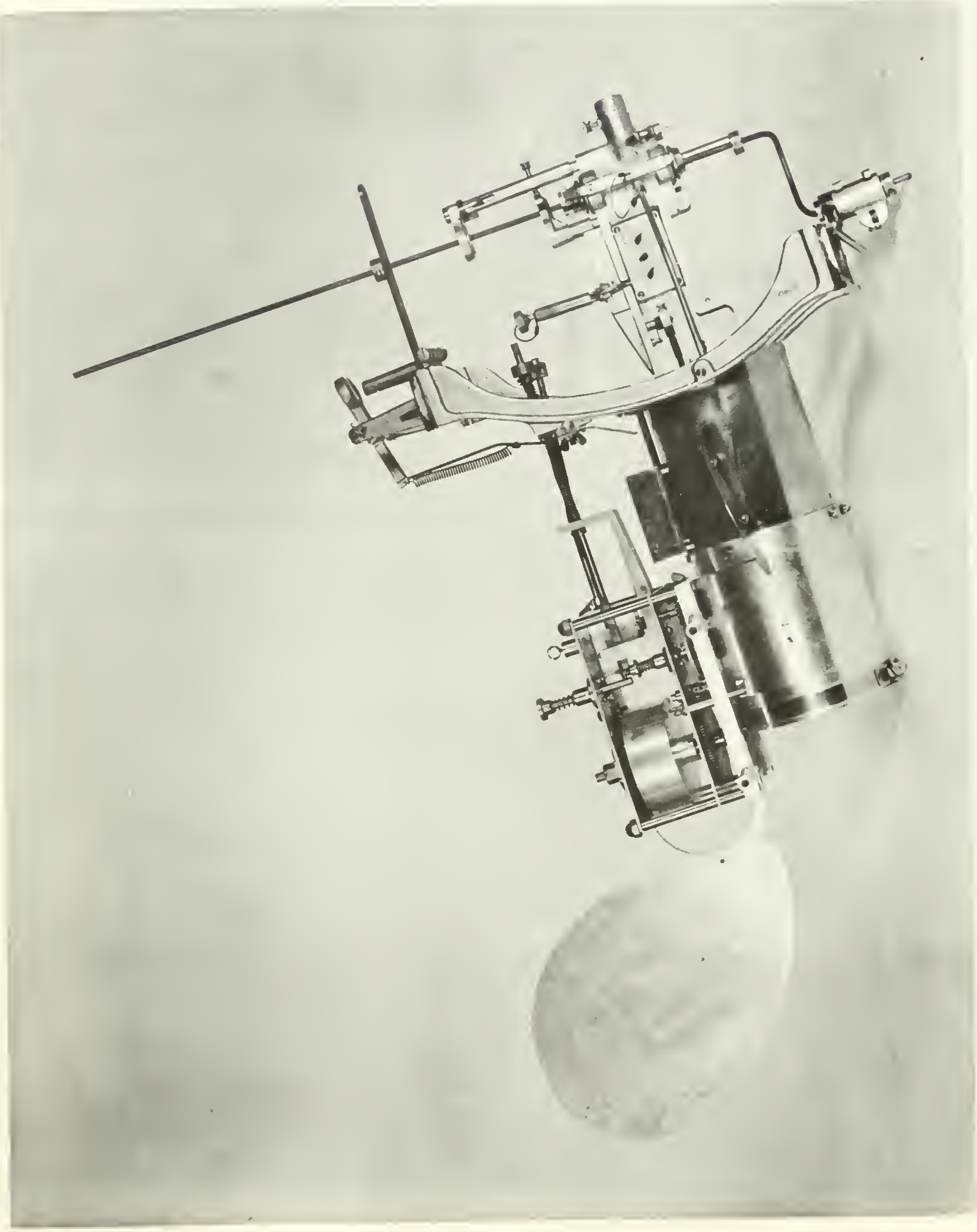


FIGURE 25
MODIFIED SAMPLER RIGGED FOR CALIBRATION

BIBLIOGRAPHY

1. Clarke G. L. and Bumpus, D. F. The plankton sampler-an instrument for quantitative plankton investigations. Limnological Society of America, Special Publication No. 5, October, 1940.

2. Clarke, G. L. and Bumpus, D. F. The plankton sampler-an instrument for quantitative plankton investigations. Limnology Society of America, Special Publication No. 5 (Revised), 1950.

3. Paquette, R. G. and Frolander, H. F. Improvements in the Clarke-Bumpus plankton sampler. International Council for the Exploration of the Sea. Journal de Conseil, 1957: 284-288.

4. Paquette, R. G. and Scott, E. L. An enlarged Clarke-Bumpus plankton sampler. Limnology and Oceanography, v. 6 (2), April, 1961: 230-233.

5. Yentsch, C. S. and Duxbury, A. C. Some of the factors affecting the calibration number of the Clarke-Bumpus quantitative plankton sampler. Limnology and Oceanography, v. 1 (4), October, 1956: 268-273.

6. Handbook of Mechanical Spring Design. Associated Spring Spring Corporation, 1955.

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The existence of a plankton sampler which is capable of filtering a reasonably large volume of water but which need not be towed in order to perform this function would provide a means whereby the planktonologist could conduct his collection in areas which preclude towing operations or under circumstances where towing is inconvenient. A modification to the standard Clarke-Bumpus quantitative plankton sampler which provides such a capability is described and a calibration procedure is discussed. Results of comparative testing indicate the satisfactory operation of the modified sampler.

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